ADVANCES IN FOOD TECHNOLOGY AND NUTRITIONAL SCIENCES

Openventio PUBLISHERS

ISSN 2377-8350

Open Journal

http://dx.doi.org/10.17140/AFTNSOJ-SE-1-102

Special Edition
"*Food Security and Food Sciences*"

Mini Review

***Corresponding author**
Marzieh Hosseini Nezhad, PhD
Assistant Professor
Department of Food Biotechnology
Research Institute of Food Science and Technology (RIFST)
Mashhad, Iran
Tel. +98-51-35425390
Fax: +98-51-35003150
E-mail: m.hosseininezhad@rifst.ac.ir

Special Edition 1
Article Ref. #: 1000AFTNSOJSE1102

Article History
Received: March 15th, 2015
Accepted: April 22nd, 2015
Published: April 23rd, 2015

Citation
Hosseininezhad M, Shafiabadi J, Hussain MA. Microbial resources to safeguard future food security. *Adv Food Technol Nutr Sci Open J*. 2015; SE(1): S8-S13. doi: 10.17140/AFTNSOJ-SE-1-102

Microbial Resources to Safeguard Future Food Security

Marzieh Hosseini Nezhad[1*], Jafar Shafiabadi[2] and Malik Altaf Hussain[3]

[1]*Department of Food Biotechnology, Research Institute of Food Science and Technology (RIFST), Mashhad, Iran*

[2]*Tarbiat Moallem University, Mashhad, Iran*

[3]*Department of Wine, Food and Molecular Biosciences, Lincoln University, Lincoln 7647, New Zealand*

ABSTRACT

For thousands of years, microorganisms have been used to process foods and to produce a variety of useful compounds, including organic acids and enzymes from fermented food products. Currently microorganisms have been employed to manufacture biotechnological products that range from alcohol and antibiotics to cellular proteins on an industrial scale. The ability of microorganisms to convert less useful substrates to value-added end-products is considered to be a novel approach to enhancing the quality and quantity of the food and the feed that we and animals eat, respectively. Exploitation of such microbial properties is an effective way to improve the nutritional quality of food as a hedge against food shortages and hunger, particularly in low income communities. This article discusses utilization of microbial resources (i.e. yeast and bacteria) to improve global food security.

INTRODUCTION

Food security is achieved when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (1996 World Food Summit, Rome).[1] Social problems can escalate the food insecurity and malnutrition in developing countries. They may result in a portion of the population being without access to sufficient levels of high quality food, and in many instances, a high percentage of this population may become malnourished. Microorganisms represent a natural resource that is available to developing and developed countries alike, which may be exploited through the field of biotechnology to supplement the current supply of food and energy.[2] Three key discoveries in the field of microbiology have advanced the application of microbial resources within the area of food science. Firstly, there has been the realization that microorganisms can be isolated and manipulated to produce desirable fermented food products. Secondly, the discovery that enzymes produced by microorganisms can be used to develop non-traditional methods for modifying foods. The third key discovery was the development of genetic engineering methods, which enable gene transfer from one species to another to move desirable characteristics into organisms of choice.[3] Additional discoveries continue to be made and technological improvements are emerging for efficient use of microorganisms in food production systems to best harness their benefits. It is important to emphasize that microbial applications are not limited only to what has been revealed to date. There are numerous unexploited areas; for example, microbial tools could potentially offer solutions to address on-going problems within the areas of food security and human nutrition. In the past, these resources received little attention. However, considerable research efforts have been made to develop microbial tools over the last decade. Low income societies could best benefit from microbial resources; however, some concerns (e.g. food safety controls) must be addressed to use them successfully.

ISSN 2377-8350 Open Journal http://dx.doi.org/10.17140/AFTNSOJ-SE-1-102

In this review, the prospects and the potential to apply microbial tools in food production systems with the intent to improve both the quantity and quality of the food supply are explored. This article will improve knowledge and understanding of the application of microorganisms and microbial resources to address the challenge of food security.[4]

FOOD SECURITY, NUTRITION AND MICROORGANISMS

Food security describes a situation in which people do not live in hunger or in fear of starvation. The stages of food insecurity range from food shortage situations to full-scale famine. Availability of food, access to food, and risks related to either availability or access are the essential determinants of food security.

The commonly used definition of food security comes from the Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA, 2000) as: "Food security exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life".[5] Adequacy of food availability means that the foods supply should potentially cover overall nutritional needs in terms of providing energy and all essential nutrients. At the same time, it should be safe, free of toxic elements and contaminants, and be of good sensory quality.

Considering projected world population growth and the increase in world demand for food over the next two to three decades, increase in food production must be achieved using less labor, water, cultivated land and/or unconventional resources. Microbial resources are being used to make or modify food products to enhance properties such as taste, shelf life, texture and nutritional value.

Microorganisms have been used widely for hundreds of years to produce various types of foods that are both nutritious and spoilage resistant. They play an important role in the conversion of ingredients into food; for example in the preparation of bread, cheese, yoghurt, fermented fish, fermented meat and vegetable products. The value-added bio-products are increasingly produced in technologically advanced countries for use in food processing. Biotechnology in the food processing sector makes use of microorganisms for the preservation of food and the production of a range of value-added products such as enzymes, flavour compounds, vitamins, microbial cultures and food ingredients. The selection and manipulation of microorganisms can lead to the production of food products and ingredients with improved processing, quality, safety, consistency and yield. These attributes of microbial tools demonstrate that bio-processing could contribute to food security by providing food elements, including protein, and minimizing the wastage and loss within the food supply chain.

Novel foods produced through the use of microorganisms can be categorized into three groups: (1) genetically modified viable microorganisms; an example is genetically modified lactic acid bacteria used in fermented milk, (2) foods produced from, but not containing, genetically modified microorganisms; an example is extracellular products of genetically modified microorganisms, such as vitamins, organic acids, etc., (3) foods isolated from microorganisms; these include new products based on single-cell protein production such as the fungus *Fusarium graminearum*, and omega-3 fatty acids derived from algae, like *Crypthecodinium cohnii* and *Nitzschia alba*.[3]

Microorganisms as an Alternative Source of Protein

The demand for human food and animal feed proteins from non-conventional sources has increased, particularly in developing countries. Microbial protein can be considered a source of additional proteins in the diet. In this application, microorganisms primarily act as production agents rather than as principal raw material. The protein content may have high biological value, especially when methionine supplementation is used.[6]

Microbial cells grow rapidly and accumulate a high amount of protein. This could be a stable source of protein, as the cultivation of microorganisms under controlled conditions yields high biomass, and the process is less dependent on variations in climate, weather and soil.[7] Microbial proteins must be evaluated for nutritive value, safety, and economic considerations before mass production is undertaken. Although animal proteins are considered the best quality proteins,[8] microbial protein, also known as single cell protein, is one of the important optional proteins because of its higher protein content and the very short growth cycle of microorganisms, thereby, leading to rapid biomass production.[9] Moreover, microbes are able to grow on inexpensive nutrient sources (substrates) to produce nutritionally rich biomass (source of high quality protein).

Such production of Single Cell Protein (SCP) for use in human food and animal feed is vital and offers the possibility to overcome a protein shortage, thus enhancing future food security. It is important to note that the microbial protein can become a major component of human diet. There will be less protein available from plant sources due to shortage of crop production and an increase in the demand for protein in future. In other words, microbial protein is – crucially required to meet global needs, in particular, in populous regions.

Candidautilis has been used industrially in the production of SCP for food, waste treatment and the production of chemicals that are used as flavor enhancers.[10] Yeast (*Saccharomyces cerevisiae*) is the most promising source used to produce single cell protein with inexpensive raw materials. It is also easy to harvest due to the larger cell size and flocculation ability with lower amounts of nucleic acids compared to bacteria.[11] The microbial protein has also been reported to contain a more favourable balance of the essential amino acids and a better biological score than soya protein.[12]

ISSN 2377-8350 Open Journal http://dx.doi.org/10.17140/AFTNSOJ-SE-1-102

The idea that SCP could be used on a large scale in food diets for human consumption has been denied because of the fear that it may contain some toxic compounds. This is not supported by any objective reasoning, since lactic acid bacteria are being digested directly through fermentation and in dairy products. The purine nucleic acids are the only SCP component which may cause problems if fluid intake is low. However, with sufficient liquid intake, there is no ill effect. Bacterial SCP is not unique in this regard, as some other foods, like meat and eggs, are rich in purines.[13]

Bioconversion of Agro-Industrial Wastes by Microorganisms and their Application

Agricultural activities and the food industry generate considerable quantities of residual plant biomass, which is considered to be "waste". This "waste" is rich in organic matter, and it therefore has considerable value if it can be reconstituted into new materials to manufacture value-added products. At present, biodegradation is the main research direction for food waste resource processing methods.[14] Potentially these huge amounts of waste can be converted into various different products, including biofuels, chemicals, cheap energy sources for fermentation, improved animal feeds and human nutrients and food. Agricultural wastes are widely available, renewable and virtually free, hence they can be important resources. They can be used to enhance food security mainly through their use as bio-fertilizers and soil amendments, animal feed, and in energy production. Many of them can be directly added to the soil without any risk to the environment.[15] Therefore they should be considered as a resource that can be utilized and not just discarded. Many researchers have determined the feasibility of using agro-industrial wastes for microbial production and evaluated protein quality of Single Cell Protein (SCP) biomass. [12,16,17]

A diverse spectrum of microorganisms for efficient cellulose hydrolysis, mainly fungi and bacteria, have been isolated and identified, and this list continues to grow rapidly, although only a few microorganisms have been studied extensively and employed widely in commercial applications.[18] *Candidautilis* has been used industrially in waste treatments. Two-step dual fermentation can be carried out using *C. utilis* with organisms like *Saccharomycopsis fibuliger*, which produces amylases and can be used in starch wastes, and *Trichodermareesei*, which has cellulase and can be used in waste treatment.[10]

Olayinka discussed how appropriate application of microbial symbiots of plants such as *Arbuscular Mycorrhizal* Fungi (AMF) could improve food security by increasing the overall yield of important staple crops, irrespective of the mechanism by which it occurs (e.g. improved phosphate acquisition, improved drought or disease resistance).[19] "Food security crops" refer to crops that can feed a significantly large number of people and that their yields fluctuate little during periods of major climatic perturbation.[19,20]

Pineapple waste was also used as sole carbon source in different concentrations for the preparation of fermentation media on which two strains of yeasts, *S. cerevisiae* and *Candida tropicalis* were grown.[21] An increased concentration of pineapple hydrolysate enhanced the biomass yield and the protein formation within yeast cells. This study presented SCP production using pineapple wastes as an inexpensive and readily available agro waste substrate material.

Sabiiti briefly reviewed how agricultural wastes could be used to enhance food security and conserve the environment. Although it is recognized that the accumulation of waste has enormous ill effects on humans and the environment, such waste if properly managed could be considered a bio-resource for enhancing food security in small holder farming communities that could not afford the use of expensive inorganic fertilizers. Microbial processing is a way to follow this target.[15]

Bacha, et al. studied *S. cerevisiae* production from potato and carrot peels. They suggested that this organism could efficiently use waste, and the biomass produced could potentially be used as a protein source in various food formulations.[12]

Fermentation and Food Security

Fermentation is one of the oldest transformation and preservation techniques for food.[22] This biological process allows not only the preservation of food but also improves its nutritional and organoleptic qualities. Fermentation technologies play an important role in ensuring the food security of millions of people around the world, particularly marginalized and vulnerable groups. This is achieved through improved food preservation, increasing the range of raw materials that can be used to produce edible food products and removing anti-nutritional factors to make food safe to eat.[23] Caplice, et al. reviewed the role of bacteria in the preservation of foods by fermentation and outlined a brief description of some important fermented foods from various countries.[24]

The major roles of fermentation are (1) preservation of food through the formation of inhibitory metabolites such as organic acids, bacteriocins, etc.; (2) improving food safety through inhibition of pathogens or the removal of toxic compounds; (3) improving the nutritional value and organoleptic quality of the food.[22]

Fermentation is a slow decomposition process of the organic substances that are present, induced by microorganisms or enzymes. Using bacteria and yeast, this was originally used as a method of preservation, but the process has been developed and understood further since then.[25] The methods are now more fully exploited to alter the texture and flavor of foods as well as to incorporate substances which are beneficial to the health of consumers.[25] Currently, the term fermentation is used to describe a special class of food products that are characterized by various

ISSN 2377-8350 Open Journal http://dx.doi.org/10.17140/AFTNSOJ-SE-1-102

types of carbohydrate that are metabolized in the presence of microorganisms, but seldom is a carbohydrate the only constituent acted upon.[26] These processes not only give food a pleasant taste, texture and smell, but it causes changes that reduce the growth of unwanted food microbes which improve the food's storage life, food safety and security. Nowadays, fermentation is used to make a wide range of foods and beverages. The process improves the nutritional value of foods using easily available seasonal raw materials and without the requirement for sophisticated processes and infrastructure facilities. Therefore, it can play an important role in preventing food shortages. Fermentation is a cheap and energy efficient means of preserving perishable raw materials and is accessible to even the most marginalized, landless, physically incapacitated rural, peri-urban and urban poor.[26]

An authoritative list of microorganisms used in food was established as a result of a joint project between the International Dairy Federation (IDF) and the European Food and Feed Cultures Association (EFFCA). This list was published in 2002 by Mogensen, et al. Table 1 shows some of the important microorganisms used in the production of fermented foods.[27]

Fermentation technologies can play an important role in ensuring food security. Many researchers have emphasized this fact in their case studies. Betsche, et al. described fermentation as a tool which could be applied to improve the nutritional value of African yam bean.[28] Quave, et al. discussed fermented foods for food security and food sovereignty and the role of fermentation in the production of local foods for health as well as its connections to community vitality.[29] Moreover, there are several examples of fermentation by-products that can be safely fed to animals and hence further strengthen the livestock system.[26] Food security can be achieved through improved food preservation, and increasing the range of raw materials that can be used to produce fermented food products. This technology, therefore, can be one of the tools which are used to combat the problem of malnutrition in developing countries.

SUMMARY

The world is facing a food shortage that will intensify in the next several decades as the global population increases. In addition to the obvious effects and enormous impact on human health, food shortages may cause political instability and challenge global stability.

Food shortage in developing countries demands exploration of new, innovative and unconventional protein sources to fortify the human diet. Taking advantage of the unique properties of microbes is one of the most promising ways to achieve inexpensive and sustainable approaches to improving productivity. The importance of microorganisms, including bacteria and yeasts, in food formulations and production systems to meet the food supply demand of the growing population, cannot be underestimated. Microorganisms can play an important role in increasing food security by promoting agricultural plant and animal biotechnological food production. Production of agricultural plants and animals is greatly influenced by the microorganisms that are associated with them. Fermentation technologies using beneficial microorganisms can also play an important role in ensuring food security through improved food preservation and production of fermented food products.

Investigations and investments are needed in both ba-

Microorganism	Type of microorganism	Used in fermentation of
Acetobacterfabarum	bacterium	chocolate
Acetobacterfabarum	bacterium	coffee
Acetobacterlovaniensis	bacterium	vegetables
Acetobactermalorum	bacterium	vinegar
Bacillus sphaericus	bacterium	stinky tofu
Bacillus stearothermophilus	bacterium	chocolate
Bacillus subtilis	bacterium	chocolate
Bacillus subtilis	bacterium	natto
Bifidobacteriumadolescentis	bacterium	yogurt
Bifidobacteriumlactis	bacterium	dairy
Candida colliculosa	fungus	cheese
Candida colliculosa	fungus	kefir
Debaryomyceskloeckeri	fungus	Limburger cheese
Dekkerabruxellensis	fungus	beer
Enterococcus faecalis	bacterium	soy sauce
Enterococcus faecium	bacterium	Manchego cheese
Enterococcus faecium	bacterium	ham
Enterococcus faecium	bacterium	pickle
Lactobacillus acetotolerans	bacterium	fruit
Lactobacillus acetotolerans	bacterium	vegetables
Lactobacillus acidifarinae	bacterium	sourdough bread
Lactobacillus cacaonum	bacterium	chocolate
Lactobacillus casei	bacterium	Idiazabal cheese
Lactobacillus casei	bacterium	Manchego cheese
Lactobacillus casei	bacterium	Roncal cheese
Lactobacillus casei	bacterium	yogurt
Lactobacillus johnsonii	bacterium	dairy
Lactobacillus johnsonii	bacterium	sourdough bread
Lactobacillus rhamnosus	bacterium	Grana Padano cheese
Lactobacillus rhamnosus	bacterium	Parmigiano-Reggiano cheese
Leuconostoc spp.	bacterium	olive
Proteus vulgaris	bacterium	surface-ripened cheese
Pseudomonas fluorescens	bacterium	yogurt
Tetragenococcuskoreensis	bacterium	kimchi
Yarrowialipolytica	fungus	dairy
Zygotorulasporaflorentina	fungus	kefir
Zymomonasmobilis	bacterium	palm drink

Table 1: A list of some microorganisms used in the production of fermented foods.

sic and applied research to better understand the mechanisms by which microbial communities influence plant and animal productivity as well as biotechnological food production. More discoveries are continuously being made and technological improvements are constantly designed, suggesting that the use of microbes in food production, and the benefits that come with their use, are not limited to what has been revealed to date. A microbe-mediated increase in global food security would be an outcome well worth the investigations and related investments that may go into them.

REFERENCES

1. World Food Summit 13-17 November 1996 Rome, Italy. World food summit plan of action. Website: http://www.fao.org/docrep/003/w3613e/w3613e00.HTM. 1996; Accessed 2015.

2. Ruane J, Sonnino A. Agricultural biotechnologies in developing countries and their possible contribution to food security. *J BioTech*. 2011; 156(4): 356-363. doi: 10.1016/j.jbiotec.2011.06.013

3. Lee YK. Food production involving microorganisms and their products. *Microbial Biotech*. 2006; 221-226. doi: 10.1142/9789812774163_others02

4. Swain MR, Anandharaj M. Ray RC, Praveen Rani R. Fermented Fruits and Vegetables of Asia: A Potential Source of Probiotics. *Biotech Res Int*. 2014; 2014: 250424. doi: 10.1155/2014/250424

5. Chicago United States Department of Agriculture. Food and Nutrition Service. The National Nutrition Safety Net: Tools for Community Food Security. *Food and Nutr*. 2000; 314.

6. Kirsop B. Food from micro-organisms. *Proceedings of the Nutrition Society*. 1985; 44(01): 13-17.

7. Kuhad RC, Singh A, Tripathi KK, Saxena R K, Eriksson KEL. Microorganisms as an alternative source of protein. *Nutr Rew*. 1997; 55(3): 65-75. doi: 10.1111/j.1753-4887.1997.tb01599.x

8. Saima M, Akhter MZ, Khan U, et al. Investigation on the availability of amino acids from different animal protein sources in golden cockerels. *The J Anim Plant Sci*. 2008; 18 (2-3): 53-56.

9. Bekatorou A, Psarianos C, Koutinas AA. Food grade yeasts. *J Food Tech. Biotech*. 2006; 44 (3): 407-415.

10. Pai JS. Applications of Microorganisms in Food Biotechnology. *Ind J Biotech*. 2003; 2(3): 382-386.

11. Wolf PS, Bindraban JC, Luiten LM. Exploratory study on the land area required for global food supply and the potential global production of bioenergy. *J Agri Syst*. 2003; 76(3): 841-861. doi: 10.1016/S0308-521X(02)00077-X

12. Bacha U, Nasir M, Khalique A, Anjum AA, Jabbar MA. Comparative assessment of various agro-industrial wastes for Saccharomyces cerevisiae biomass production and its quality evaluation as single cell protein. *J Anim Plant Sci*. 2011; 21: 844-849.

13. Ekeroth L, Villadsen J. Single cell protein production from C1 compounds. *Biotechnol (Reading, Mass)*. 1990; 18: 205-231.

14. Lan Y, Zhang Y, Liu Y, Sheng Y, Shi W, Liu Y. Research on food waste resource utilization and processing technologies. *Adv Biomed Eng*. 2012; 7: 105-109.

15. Sabiiti EN. Utilising agricultural waste to enhance food security and conserve the environment. *African J Food Agri Nutr Develop*. 2011; 11(6).

16. Mondal AK, Sengupta S, Bhowal J, Bhattacharya DK. Utilization of fruit wastes in producing single cell protein. *Int J Sci Environ Technol*. 2012; 1(5): 430-438.

17. Santana-Méridas O, González-Coloma A, Sánchez-Vioque R. Agricultural residues as a source of bioactive natural products. *Phytochem Rev*. 2012; 11(4): 447-466. doi: 10.1007/s11101-012--9266-0

18. Howard RL, Abotsi E, Van Rensburg EJ, Howard S. Lignocellulose biotechnology: issues of bioconversion and enzyme production. *African J Biotech*. 2004; 2(12): 602-619.

19. Olayinka A. Soil microorganisms, wastes, and national food security. *Obafemi Awolowo University Press*. 2009; 222.

20. Rodriguez A, Sanders IR. The role of community and population ecology in applying mycorrhizal fungi for improved food security. *The ISME J*. 2014. doi: 10.1038/ismej.2014.207

21. Dhanasekaran D, Lawanya S, Saha S, Thajuddin N, Panneerselvam A. Production of single cell protein from pineapple waste using yeast. *Innovat Rom Food Biotechnol*. 2011; 8: 26-32.

22. Bourdichon F, Casaregola S, Farrokh C, et al. Food fermentations: microorganisms with technological beneficial use. *Int J Food Microbiol*. 2012; 154(3): 87-97. doi: 10.1016/j.ijfoodmicro.2011.12.030

23. Battcock M. Fermented fruits and vegetables: a global perspective. *Food & Agriculture Org*. 1998; 134.

24. Caplice E and Fitzgerald GF. Food fermentations: role of microorganisms in food production and preservation. *Int J Food Microbiol*. 1999; 50(1): 131-149. doi: 10.1016/S0168-1605-(99)00082-3

ISSN 2377-8350 Open Journal http://dx.doi.org/10.17140/AFTNSOJ-SE-1-102

25. Stahl U. Food biotechnology. *Springer*. 2008.

26. Hasan MN, Sultan MZ, Mar-E-Um M. Significance of fermented food in nutrition and food science. *J Sci Res*. 2014; 6(2): 373-386.

27. Mogensen G, Salminen S, Obrien J, et al. Food Microorganisms- health benefits, safety evaluation and strains with a documented history of use in foods. *Bulletin of IDF*. 2002; 377: 4-19.

28. Betsche T, Azeke M, Buening-Pfaue H, Fretzdorff B. Food safety and security: Fermentation as a tool to improve the nutritional value of African yam bean. *Conference proceeding from the International Agricultural Research for development*. 2005; 1-5.

29. Quave CL, Pieroni A. Fermented foods for food security and food sovereignty in the Balkans: a case study of the Gorani people of Northeastern Albania. *J Ethnobiol*. 2014; 34(1): 28-43.